Architectural and Environmental Compositional Aspect for Technological Innovation in the Built Environment

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Abstract

This paper focuses on the complex relationship between historical building design a projects, both from compositional and environmental points of view. In spite contradictions in their nature, their integration is essential from the very both to improve and efficiently preserve the environmental and architectural qu this work is to define a number of guidelines to support and inform the des and eventually ensuring the quality of the built environment, both aesthetically and environme end, the paper explores the use of climatic and microclimatic analysis as a and sustainability performance of future buildings. In particular, the work microclimatic matrix, as support to the climatic considerations about differe and cooling systems; and to the architectural/compositional approach defin

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1. Introduction

The building sector, excluding industrial buildings, is responsible for almost 40% of total pr consumption in developed countries [1]. This percentage includes energy demand for space heatin cooling, hot water production, lighting, cooking and appliances. In addition, considering the warming effect as a result of the trend of greenhouse gas emission, the energy consumption for space in several countries [2,3]. Within this framework, a passive approach to building des taking envelop rather than HVAC system as the main technology for environmental c reducing energy consumption in the building sector. This approach can contribute to curb trend related to carbon emission-dependent space air conditioning systems. technologies able to increase the energy performance of building are consolidated and incentivized legislation, standards, and codes of practice. In addition, passive solar gains and hybr and mitigating internal gains in summer, solutions for increasing solar gains in winter, are well known even if, especially for cooling, more widespread could decrease drastically the energy need for heating and cooling a building. However, to reach much more stringent goals near-zero-energy buildings (NZEB), as set by EPBD 2010/31/EU by 2020, or, even more, th positive-energy building (NPEB), a much stronger effort than currently done to i impact technologies to a sustainable architectural design approach needs t In spite the scientific progresses achieved in the studies of environmental debate about the aesthetic of sustainability seems to have been left behind professionals and academics. The projects categorized as sustainable are often defined either according to th type of environmental systems and technologies utilised, as well as the architectural design approach. The contemporary examples of best sustainable different aesthetic approaches that designers seem to have undertaken. T more literal design solution of environmentally aware buildings, in which t was conceived as a design tool; to the more technology oriented approaches, where environmental artificial systems became expression of architectural aesthetic. Examp

these approach can be considered: 1) the Jacob House 2 built by Frank Lloyd Wright in Wisconsin, W
United States, built between 1944-1948, in which the incidence of the solar light was lite
the building and the floor plan; to the 2) the environmental houses larg
technological features were heavily applied to the buildings without much design i
more sophisticated example of high tech buildings such as the Centre du Po
France, built between 1971-1977. The architectural agenda of sustainability seems therefore t
the mimetic tendencies of relating to the environment in a literal manne
sustainability by expressing the efficiency of the technological features of p
integration seems not to be explored or discussed as much. This happens
software and tools that can assist the design process, by integrating microc
systems and technologies analysis. This paper will explain in the next sections how s
1) offer support to the design process; 2) enhance the integration betw
technological systems; and 3) contribute to the definition of the aesthetic of sustainabilit

2. The preliminary design process

According to Nigra and Maffei[4] the delivery process of building projects can be subd
theoretical areas such as: building opportunity generation; building sco
production; building erection; building functioning and control. Each of these pha
from conception to construction, is characterised by a number of instances in which the
design choices and technological systems can be critical to enhance the
performance of projects. Specifically, this paper will deal with the area of p
design process, as critical moment to explore the integration between a
technological features. Several researchers[5] explained that the earliest involvement of
awareness in the design process, the more cost, time, and quality effect
Moreover, Gibbs[6&7] together with Cherns[8] pointed out a number of critical considerations during
the phases of building design programming and building preliminary design
clients need, the building scope and the building characterisation, regulation and design program
another important part of the preliminary design, the site analysis, represents a critical aspect of in
between environmental awareness and architectural design approach. The s
wind, light, ground, water, surrounding buildings, and urban regulations, has the potential to drama
building orientation, dimensions, interrelation, and localization, as well
approach. During the preliminary building design, technical and environmental contribute
informing geometry, volumes, colours, construction systems selection, and
As the flow chart in Figure 1 shows, the building design program phase
compatibility and performance assessment of choices related to the definition of virtual spa
result of fulfilment of both functional and environmental requirements. Thes
determining design objectives, activities to be performed and users needs, as well as
laws, standards, and regulation at various scales. On the side, but often not less
not considered part of the building programming, represents an essential operation for the c
compatibility assessment of building design choices.

3. Environmental aspects of the preliminary design

The environmental aspects of the preliminary design process are related to
affecting the impacts of the building on the physical context at various spatial scales, ca
global, regional, local, and indoor/outdoor as well as temporal: hourly, running concer
the building and its entire life cycle.
Environmental assessment implies different approaches and methods at di
preliminary design phase, two types of analysis are, generally, considered: envi
programming and site analysis. After a brief description of the framework, this paper will focus on
particular attention to site climate evaluation.

3.1 Environmental building programming

Environmental building programming follows a performance-based approach and a characteristic process of
analysis and assessment from user needs and activities to requirements, a
definition, according to the compatibility (environmental) loop above descri
During this process, various tools, such as diagrams, checklists and matrices, can be a
Examples of these applications are numerous, but generally they do not deal with environmental [9,10&11].

Fig. 1. Flow-chart of the preliminary design process based on a performance-driven approach (image modified from [6]).

The main actions to be carried out in the environmental building programmi

- reception of the client brief including building design objectives and users needs;
- reception of laws, standards and regulations related to the building type t
- list and classification of activities and relevant environmental requirements;
- analysis of input/output flows related to the activities and affecting the environment, both outdoor and indo
- list and classification of functions related to the activities;
- definition of virtual space units as spatial representations of aggregated functions;
- definition of dimensional (order of magnitude) and environmental requirements of virtual space unit

- aggregation of virtual space units according to their reciprocal linkage characteristic
  compliance to the defined environmental requirements;
- alternative configurations of virtual space layout.

A virtual space does not have physical boundaries but just potential links withi
and with the external context. These potential links are related to various aspects:
geometry, communication, physical phenomena (airflow, daylight, solar radiation). The environmental buildi
programming focuses on some of these aspects, the ones which have an imp
as mentioned above.

3.2 Site-climate analysis

The site analysis phase of a preliminary design process concerns various
transportation, landscape, socio-cultural issues, town planning, land use, economic value,
impacts. Within the latter, the site-climate analysis is aimed at evaluating the potential vocatio
site to locate an activity, or a virtual space, or a building, with regard to thermal comfort as a funct
factors such as solar radiation and wind flow [7, 8, 12]. The site-climate analysis uses the site microclimate matrix
(SMM) as a tool allowing for optimising the location of outdoor activities, space units,
i.e., buildings, in relation to thermal comfort. The underlying methodology behind it was introduced
by two American scientists [2] and modified by [1, 7]. It allows designers to locate properl
to a sustainable and bioclimatic approach, the virtual space units defined in the building
programming phase described above. SMM can also be used to optimally study the outdoor of buildings
urban design by evaluating the influence on exposure/protection to solar radiation and win
either for new assets or in a specific existing context.
An SMM is elaborated as a graphic overlay output from the analyses of solar shading and airflow dynamics
on a lot resulting on a four variable zoning derived from the combination of shaded/sunny and
windy/sheltered zones (Fig. 2). This zoning is called matrix because it is discretized by a norm
cells are characterized by one of the four variables. Each variable is then associated to a pote
level (see Table 1) in order to assess its vocation as a recipient of activities.
The SMM is built on a virtual plane, which is generally at the ground level, yet it is possible to use
different matrixes by changing height or to create a three-dimensional matrix of the project site.
depends on the specific needs, however, three-dimensional analyses require a higher
investment in terms of time, cost and computer capacity, more dimensional CFD software for airflow
studies. It is advisable to proceed with the analysis of the lot where the building under design, or retro
in order to evaluate the mutual influences between close and distant buildings

Fig. 2. Example of wind wake core analysis in winter and summer (point 4) for a construction lot in
The airflow analyses were conducted by using the software KARALIT CFD.

Theoretically, SMM changes over time following daily, and hourly apparent sky position of the sun and the seasonal (or monthly, daily, hourly) prevailing wind direction considered. However, SMM, being used as a design parameter, is referred to extreme climate conditions a during solstices, morning and afternoon, and relevant seasonal prevailing. As an example, the reference dates for Southern hemisphere are 21 December at 10:00 and 14:00 and 21 June at 8:00 and 16:00. It is possible to choose different times in the hottest and the coldest day of the year, estimating them by using the typical meteorological year (TMY) of the locality or as general reference 21st July and 21st January at 9:00, 12:00 and 15:00 [5]. When the calculation of shadi conducted by using specific software, it is important to pay attention to the correct time definition (local Meridian, reference Meridian, solar hours).

The following steps shall be performed to elaborate a SMM:

1. definition of the context and construction surrounding buildings and natural obstacles;
2. discretization of the analysed lot by a normal grid with cells dimensi (for example, 5x5 m);
3. analysis of solar path and relevant shading dynamics in different reference days and hours;
4. seasonal analysis of wind wake core (see Figure 2) or different temporal analysis, for example day-night breezes);
5. overlapping of the results from the analyses (steps 3 and 4) on the grid defined in step 2 in order to classify each cell by a 2x2 matrix of microclimate conditions (sunny-windy, sunny-calm; shaded windy, shaded-calm); this process is repeated for the considered hours and days (see Figure 3);
6. assigning a score to the four classes identified, considering the activities for each matrix developed in step 5 (Table 1);
7. construction of a time-referenced SMM for each type of activities/functions/space u

In Figure 2 wind wake core seasonal analysis is applied to a specific lot in Melbourne, Australia. The prevalent wind directions are North in winter (from hills to sea) and South in summer (from sea to land), and a change in directions occurs during the day/night breeze regime. These analyses were carried out using the CFD software [13]. Existing building context redu wind velocity at the ground floor in the East side of the construction lot, c natural ventilation. At the same time, on the same side, Venturi effect is evident, consequent increases in the wind velocities. The presence of high-rise buildings could represent an effective solution for this potential discomfort situation.
Wind analyses could be conducted in different ways: CFD software, which needs specific aerodynamic knowledge and is time-consuming and costly; wind tunnel simulation, which re physical model, specific knowledge and laboratory availability; simplified methods based on statistical correlation of wind tunnel test data on rectangular modules with varyi incidence angles such as the one elaborated by Grosso [7] on the basis of a previous research [14]. The score assigned to each cell of an SMM, as indicated in the classification step, is based on potential outdoor comfort conditions related to types of activities and their metabolic rate; it can be assess on a qualitative scale (Table 1) or using quantitative values

Activities		Season	Relation between site microclimate m conditions			
			shaded calm	shaded wind	sun-calm	sun-wind
Low metaboli rate	Stay; wal around	Winter	Unfavoura	Worst	Optimal	Good
		(cold win	Good	Worst	Optimal	Unfavoura
		Summer	Optimal	Good	Worst	Unfavoura
		(high RH)	Unfavoura	Optimal	Worst	Good
Medium metaboli rate	Walking slow runni	Winter	Unfavoura	Worst	Good	Optimal
		(cold win	Good	Worst	Optimal	Unfavoura
		Summer	Good	Optimal	Worst	Unfavoura
		(high RH)	Unfavoura	Optimal	Worst	Good
High metaboli rate	Run fast; activities	Winter	Worst	Unfavoura	Good	Optimal
		(cold win	Good	Worst	Optimal	Unfavoura
		Summer	Good	Optimal	Worst	Unfavoura
		(high RH)	Unfavoura	Optimal	Worst	Good

Tab 1: A classification of outdoor thermal comfort conditions in relation to the microclimate matrix variable types of activities.

As an example of a quantitative assessment, a score could be, for a high m
running: in winter, 1 for calm-shaded, 2 for windy-shaded, 4 for sun-calm, 5 for windy-sunny; in summer, 1
for sun-calm, 2 for windy-sunny, 4 for calm-shaded, 5 for windy-shaded.

3.3 Architectural/compositional implications

The SMM presented above was used as design base for a research conducted in the Master of Architecture Sustainability of the Polytechnic University of Turin. The call of the atelier was to de
design proposal for a new university building in Melbourne, following the ex
Building and planning faculty at The Melbourne University.

In this atelier, the microclimatic analysis was applied to the early stages of the design process, to infor
the decision-making process on a compositional level.

As showed in figure 3 and 4, the microclimatic analysis produced a reading of the site that sh
of calm (wind and sun) over different time of the year. By analyzing the sit
was defined optimizing the volumetric definition of the buildings; shape the
volumes; define the internal spatial layout and allocation of functions; and determine
characteristics of each façade profile (figure 4). This latter allowed the design of a
which pattern, shading systems, and glazing features where equally balance
and surfaces exposures (figure 6).

Fig 3: Example of calculation of a microclimate matrix as basis for a volumetry study (students: Mahak P.Tootkabo
Danial Mohabat Doost, and Xiaochen Song).

The definition of the volumetric organization allowed the definition and the
the design proposed. Figure 5 shows an example of solar exposure analysis in whic
mapped according to incidence of the sun on each its part. This analysis
decisions on the shading devices design as well as the façade perforation pattern (fig
6).

Further analysis was also utilised to determine the performance and spe
components defined in the project proposal. Specifically, glazing charac
ventilated façade, curtain screen were selected for each façade, according the exp
characteristics, elaborated in the microclimatic analysis.

Fig4: Example of design process in which the volumetric organization was defined to the characteristics of the site, previously explored by the microclimatic analysis (study by Mana P. Tootkaboni, Danial Mohaba
Xiaochen Song).

Fig5: Example of solar exposure analysis on the design proposal for the site (study by Mana P. Tootkaboni, D
Mohabat Doost, and Xiaochen Song).

Fig6: Example of design process to establish modules, patterns and shading devic
according to the solar analysis on the façade, climatic analysis (case study by Mamak P.Tootkaboni, D
Mohabat Doost, and Xiaochen Song).

4. Discussion

The use of SMM showed a number of aspects that can enrich the design process
providing design alternatives; 2) the assistance in the definition of technologies and specifications; 3) the
contribution to the selection of the appropriate construction systems; 4) ensuring quality thr

1. The ability of providing design alternatives could be referred to the ab of volumetric configuration and location within the site; the definition relation to the building orientation, climate and use(s) of the land; the inclusion (o natural elements found on site as architectural features; and the characteristics as main concept for the overall design approach. Moreo can also inform elements of façade design such as the relation betwe shading configuration and location; colours and patterns diffusion, elements; orientation and type of façade elements.
2. The use of SMM can also assist in the definition of technologies and speci the relation between performance required and positions within the b

specific technical requirements and therefore of required elements; highlighting the opportunity of innovative/non-conventional design elements or details.

3. The awareness of the microclimatic configuration of a site could assi appropriate construction systems, by an accurate analysis of areas of the futur could be design or treated with the use of different construction sys contribute in saving in cost and time by applying the use of construction. Moreover, the results of a microclimatic analysis could as well info construction systems.
4. The ability of designing buildings that embed the site-specific conditions can also contribute better conditions throughout the life span of the building itself. Not only architec more effective choices in terms of construction systems, and technolo of sustainability over time.

Fig 7: The image shows the design parameters that can be informed by the use of microcl of the design process and delivery. Above the blue band the design process is characteristics. Below the blue band the design parameters that can be enrich/integrated by the use of -climatic analysis are listed for each phase of the design process.

Figure 7 summarizes a number of parameters that can be modified and informed by the use o analysis throughout the design process and delivery. In the image the design process is descr phases and related to all the design parameters that can be ... The ability of relating the use of site-climate analysis, design phases and design parameters represents that can be applied through all the phases of projects delivery. This me

considering technical parameters, and optimizing design solutions, without impinging on the design process, which instead informed on a number of potential... Moreover, this des
methodology could assist the development of requirements schedules for each technical elemen
support the testing the quality of design choices and their optimization.

5. Conclusions

Environmental building programming and site-climate analysis can provide designers and ar
ability of open an informed discussion on the role of design within the sust
Having a number of design alternatives directly informed by the environment
a new architectural language that gathers the approaches that have been taken so fa
architecture until now, and implementing them toward an integrated languag
This language could potentially produce a variety of buildings that minimize energy consumption by
resources depletion, but that are able to express the identity of those
environmental and technological approach to design, driven by using a performance approach in the
preliminary design phase, is essential for considering these issues in the design
compositional solutions and suggesting possible optimization procedures.

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